

COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

# THE HOP APHIS.

By WARREN T. CLARKE.



Hop Yard, showing male hop plants and supply wagon.

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# THE HOP APHIS.

(*Phorodon humuli*, Schrank.)

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BY WARREN T. CLARKE.

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In certain of the hop-growing sections of California the hop aphis is at times a serious menace to the industry. Owners of hop yards dread the appearance of these minute insects on their vines, well knowing that if they increase unchecked great losses will result. Indeed, instances are known in this State where the value of the hop crop has been reduced fully one half, because of the presence of the aphis. It is known and feared in all parts of the world where hops are grown, and entomologists on the continent of Europe, in England, and in this country have devoted much study to this pest. Studies of the hop aphis here in California, however, seem to show that the results obtained in these other sections do not fully apply here, owing probably to climatic differences. This will be more fully brought out in the course of this discussion of the insect and its activities in this State.

*Spring Appearance and Distribution.*—Under the California conditions of climate and soil the first hop plants to begin growth in the spring are those bearing staminate flowers only, the males (variously called “He Hops,” “Bulls,” “Los Toros,” etc.). Leaves and runners appear upon these from ten days to two weeks before growth begins with the female or pistillate-flowered plants from which hops are gathered, and they remain green for some time after these female plants have become dry and unsucculent. The staminate-flowered or male plants are scattered about the hop yard usually in the proportion of one of these to from one hundred and fifty to two hundred of the pistillate plants, and by them pollination of the hop is accomplished. (See Fig. 1 and Frontispiece.) It seems that in the hop yards of this State the aphids invariably appear first upon the under side of the leaves of the male plants, and they can usually, in affected fields, be seen upon them from two to three weeks before any can be discovered upon the female plants. On May 2, 1903, we found upon the leaves of male hop plants in the Pajaro Valley wingless parthenogenetic\* female hop aphids and their young. In one instance the mother aphid had clustered about her seven of her offspring. The plant upon which these were

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\*Insects propagated without sexual reproduction.

found had grown out about one foot and the aphid colony was upon the lowest leaf. On the date in question and on the following day (May 3, 1903) a number of hop plants, invariably staminate ones (for indeed the pistillate plants had not yet begun to grow), were found to have aphids upon the lower leaf or leaves. Inquiry developed the fact that in the yards under observation the attack had always previously begun in the localities where these were found, the infection spreading from these points until finally large areas of the yards were affected. These starting points of the hop-aphis attack in these yards in 1903 were carefully noted, and the development, and course of the trouble observed through the year. In from fourteen to twenty-one days after the first wingless parthenogenetic female aphids were observed, an occasional winged female, also parthenogenetic, was developed. These winged



FIG. 1. General view of hop yards, showing male plants.

aphids passed to the female hop plants and the infection was thus spread pretty generally through the yards. By the time the hops began to form the aphids were very numerous and, where no remedial work was undertaken, the damage done by them was very considerable.

*Character of Injury.*—The injury wrought by the aphids upon the pistillate plants (female hops) is twofold. At first the attack is confined to the leaves and tender growing tips of the shoots, and the size of the leaves of the plants when the lice are numerous upon them is greatly reduced. So severe, indeed, was the effect upon the plants under observation that by the first of July attacked vines in the yards could be easily distinguished from the plants that were not attacked, because of the smallness of the leaves and their yellow, dry appearance. The crop upon these affected plants is of small size and light weight and greatly reduced in value. A more serious injury, however, is that



to the hop cones themselves, because of the direct attack of the aphids on the heads. The insects seem to find the young, newly-forming cones very much to their taste and gather in great numbers in them, generally at the base of the bracts. When the hops are gathered and sent to the kiln for drying, these aphids remain in place, and the result is that the finished product is of poor quality and aroma because of the dried bodies of the insects in them. This reduces not alone the value of the individually affected hops, but also of the whole lot in which they may occur. The total injury determined by comparing yards that were similar in every respect of soil, climate, and exposure, was such that the crop of the yards where no control work was attempted and where the aphids were allowed to take their full course, returned to the owners not more than one half as much per acre as did those yards where control work was done.

#### EXPERIMENTS WITH REMEDIES.

While the hop aphids appeared in the Pajaro Valley yards very early in May, 1903 (first observed May 2), they did not become numerous enough to constitute a serious menace to the crop until the middle of June. At this time they had become quite well distributed from the points of beginning, and were even occasionally to be found in the newly-forming hops; and a brisk campaign was organized against them. Through the co-operation and assistance of certain growers of hops in the region we were enabled to carry out a series of experiments in spraying on two hop yards. This work resulted in a complete control of the aphids, and very greatly increased the value of the yield in these yards over that of the adjacent yards that were not treated.

*Kerosene Emulsion and Tobacco.*—One yard, comprising some forty acres, is situated near the town of Watsonville, in the Pajaro Valley. During the third week in June the attack of the aphids in this yard became so serious that it seemed as though a large proportion of the crop would be ruined by them. The male vines in certain portions of the yard were very much infested with the aphids, and they could also be found in goodly numbers on the female vines and even in the young hops. After some minor experimenting to decide the killing power of the material and its effect on the hop foliage, we decided to treat this yard with a spray made up of tobacco decoction and kerosene emulsion in combination. The *tobacco decoction* was made by steeping tobacco stems and refuse from cigar factories for from two to three hours in water that was kept heated to just below the boiling point. One pound of tobacco refuse was used to each two gallons of water, and by this steeping process a quite strong tobacco juice resulted. The *kerosene emulsion* was made by dissolving seven and one-half pounds of ordinary

laundry soap in fifteen gallons of hot water, and to this adding five gallons of kerosene oil. The soapy water and the oil were thoroughly



FIG. 2. Spray outfit.

churned together for from fifteen to twenty minutes. This was best done by pumping back the material on itself through the spray nozzle. The result was a fairly stable emulsion of a creamy consistency. We

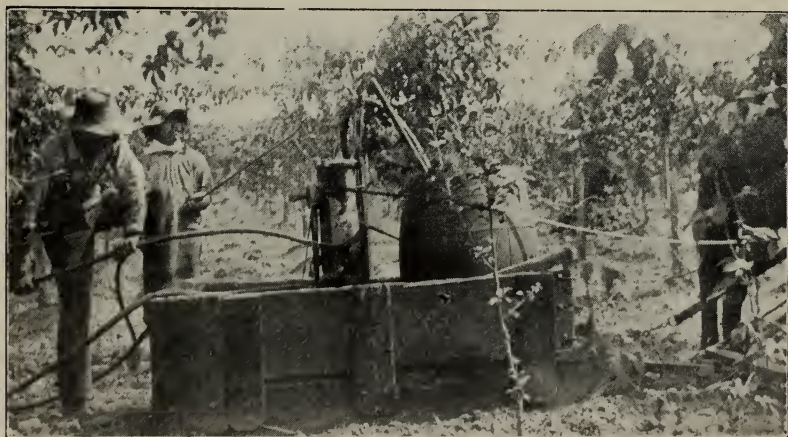


FIG. 3. Spray outfit.

found it best not to make more of the tobacco decoction than could be used up in two days, because if the material was kept longer it fer-



mented. The decoction then was not so effective an insecticide as when fresh, probably because of a breaking-down of the nicotine products under the action of fermentation. The kerosene emulsion also should not be kept too long before using, because of a tendency which even the most carefully made emulsions have to separate and allow free oil to appear.

The spray material was made up by taking forty gallons of the tobacco decoction and to it adding three and one-half gallons of the emulsion. This was stirred frequently while being applied to the vines,



FIG. 4. Spraying hop vines.

so that the mixture was of uniform quality. We found that a certain amount of separation of the oil in the spray tank was unavoidable in practice. To avoid placing this upon the vines it is best not to use for spraying the last two or three inches of material from the tank. The free oil burns the hop foliage badly, hence this residue should be emptied out before refilling the tank.

We used in this yard an outfit consisting of a fifty-gallon barrel and a good spray pump set up on a sled. (See Fig. 2.) This when loaded was not too heavy for one horse to haul quite readily. Two fifty-foot leads of hose and short rods (see Fig. 3) were found to economize labor to the best advantage, the sprayers working away from the outfit and covering five rows on each side of the one through which the horse

was driven. Vermorel (eddy-chamber) nozzles were used in this work, and great care was taken to get the spray material on the under sides of the leaves, where most of the aphids are found. (See Fig. 4.) This one outfit, employing one man to drive and pump and two men spraying, covered from three and one-half to four acres a day. We found it necessary to go over the yard three times before the hops were ready to pick, and we averaged for these three sprayings sixty gallons of material to the acre for each application, or for the entire work one hundred and eighty gallons to the acre. To economize labor, enough of the material to last a half day was made up in the morning and again at noon; and this was hauled out to the hop yard and left in a situation that would enable the men who were employed in spraying to fill up the barrel on the sled with the least possible delay. (See Frontispiece.) We found this to be a great economizer of time and expense.

The cost of the materials used was as follows: Kerosene, 24 cents per gallon; soap, 5 cents per pound; tobacco waste,  $1\frac{1}{2}$  cents per pound. Labor was worth \$1.25 a day, and the horse 50 cents a day. Using these figures as a basis we find that each of the three sprayings on this place cost less than \$2 an acre, or for the entire season's work on the fifty acres about \$240.

The results obtained by this spraying amply justify the expenditure involved. The material used was effective upon the aphids, and when the crop on this yard was gathered it was uninjured, while untreated vines and yards in the neighborhood had the value of their product, both in quantity and quality, reduced fully one half.

*Whale-Oil Soap and Quassia.*—The other hop yard in which experimental and control work was done is six miles from Watsonville, and covered nearly one hundred acres. The aphids did not spread over all this yard, and it was necessary to spray only some fifteen acres of it. Work was begun in the last week of June, as by that time the presence of the aphids was quite evident. The spray material used was made up of the extract of quassia chips, and whale-oil soap. The quassia extract was made by soaking the chips in water for a day or two and then boiling thoroughly for two hours. Seven pounds of the chips were thus treated in three gallons of water, and the extract obtained was poured into two hundred and fifty gallons of water in which nine pounds of whale-oil soap had been dissolved. This was sprayed upon the vines, the outfit used and the method of application being about the same as that previously described. The same amount of material per acre was used in spraying this yard as in the other case; that is, sixty gallons for each spraying, or a total of one hundred and eighty gallons for the season's work.

The cost of the materials used was as follows: Quassia chips, 10 cents



per pound; whale-oil soap, 7 cents per pound. The labor and the expense of a horse were the same as in the first described experiment. Figuring from this basis we find the cost of spraying with this material to be somewhat less than with the kerosene emulsion and tobacco decoction, amounting to between \$4.50 and \$5.00 per acre for the season's work. The aphids were well controlled by the spraying with this material in this yard, and no loss was caused by them here. Again, the near-by hop vines and yards not treated had the value of their product reduced fully one half by the aphids.

The experimental work in these two yards indicated that both the extract of quassia and the tobacco decoction were effective in destroying the aphids. They did not, however, spread out over the leaves in a satisfactory manner when used alone. It was also shown that neither the kerosene emulsion, nor the solution of whale-oil soap, at the strength at which it was safe to use them, were alone sufficient to effectively control the aphids. By combining the tobacco decoction with the kerosene emulsion, or the quassia extract with the whale-oil soap, the insecticidal value of both materials is fully utilized and the spreading of the liquid, so necessary for satisfactory work, is accomplished.

Though many other spray materials were experimented with, none of them controlled the aphid nearly so well as the two above described.

Probably the ease of obtaining either the tobacco waste or the quassia chips, and the cost of these ingredients of the spray at the time when purchased, will determine which of the two materials is to be used by the hop-grower.

In the treated yard the yield in hops in 1903 was about 1700 pounds per acre, and in the untreated yards the yield was on the average only 900 pounds on the same area. The fact that by treatment such as has been indicated growers have been able to double the returns on each acre of hops amply proves that careful spraying for the hop aphid pays well.

#### DESCRIPTION AND METHOD OF GROWTH OF THE HOP APHIS.

In our California yards the first hop aphids to appear in the spring, as mentioned above, are wingless females, which produce living young parthenogenetically; that is, without the male aphids being present. (See Fig. 5.) These were probably produced from eggs in which the insect had passed the winter, and correspond with what is called the "stem mother." These females when full grown are from one and one half to two millimeters (one eighteenth to one twelfth of an inch) in length. They vary in color from very pale green to dark green. They are provided with rather long antennæ set on frontal tubercles, which

are toothed internally. The first joints of the antennæ are similarly toothed. (See Figs. 5, 6, and 7.) This character of the frontal tubercles and first antennal joint serves well to identify the species. The honey-tubes or nectaries which are located on the distal portion of the abdomen, one on either side of the medial line of the dorsum, are quite prominent. The young are similar in appearance to the adults, but are smaller. The mother aphids produce their young at the rate of



FIG. 5. Wingless parthenogenetic female hop aphid of the first or spring generation. Length,  $1/18$  to  $1/12$  of an inch.

from four to six a day, and specimens kept under observation by us continued this rapid production of young for twelve days. A total of sixty-six young were produced by some of these females. These young aphids in their turn begin to reproduce their kind on about the fourth day after their birth. The rapid increase in the numbers of the aphids found upon the hop vines in infested fields is easily understood when we consider the rapidity of reproduction shown by these creatures.

In from two to three weeks after these wingless parthenogenetic females first appear winged aphids will occasionally be found. These differ from the first chiefly in having two pairs of relatively large wings, which are quite delicate in structure and almost transparent. The fore wings are much larger than the hind wings and both are rather sparsely veined in a manner characteristic of the group. These winged aphids, which produce living young in the same manner as do the wingless ones, first described, fly sufficiently well to spread the attack to other vines. Thus in a very short time what was at first a local infestation of small moment may become an attack involving large areas of the hop yard. The winged parthenogenetic females continue to be developed in about the proportion of one to a hundred wingless individuals until about picking time.

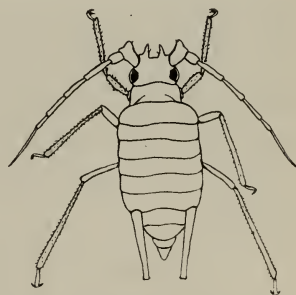


FIG. 6. Wingless female hop aphid. Late summer generation. Much magnified.

*Autumnal History.*—After the hops were picked and the pistillate plants were practically all dead, above ground, the male plants were kept under observation for three weeks. The lice continued to develop and increase materially in numbers upon these plants, yet only an occasional winged specimen was developed, as was true during the summer, and these were all parthenogenetic females. (See Fig. 6.) By the end of August or early in September the male hop plants were also all quite dead above the ground and in many

instances the yards had been closely pastured off by sheep. Before this had occurred, however, an occasional wingless oviparous female aphid was observed, and also a number of winged males; and these were always found on the lower leaves and runners of the male hop vine.

These egg-laying females differ in appearance but slightly from the females previously described, yet on examination under the microscope the eggs in them can be quite readily discerned. The winged males are the offspring of wingless parthenogenetic mothers. These differ from those aphids previously described in being rather slimmer and longer, and in being marked with black dorsally; the whole color-effect of the bodies of these males being darker than is the case with the others. (See Fig. 7.)



FIG. 7. Winged male hop aphid. Much magnified.

We were unable to actually find the eggs of the hop aphid in any of the yards under observation, nor upon any of the neighboring vegetation, but the wingless egg-laying females being produced on the male hop vine only is good presumptive evidence that the eggs are deposited there. The male hop plants on which the aphids were first found in 1903 were, in the majority of cases, the same plants on which they were found at the end of the preceding season, and in the few cases where these last infested vines were not the same that were first infested they were near neighbors of these vines. Our observations have been continued into the present year, 1904, and the same holds true, the same vines being again the first to show the presence of the hop aphid, and from them the trouble has again spread.

*Wintering.*—The California data given above seem to indicate that the hop aphid hibernates in some situation in the hop yard itself in the egg form. The eggs may be placed either upon the cut stalks of the hop vines at or just beneath the surface of the ground, or upon the roots of the plant or even in the ground contiguous to the vines. At no time have we been able to find any evidence of the presence of the hop aphid on any other vegetation near to or in the hop yards. This fact, coupled with their appearing first upon the same male plants year after year, or at least in the same parts of the yards, and their continuance upon these plants until the very end of the season, points strongly to the probability of hibernation taking place in the suggested situations. That wingless oviparous females and winged males are to



be found upon these late-growing male vines, and that these are the last forms of the aphids to be produced in the hop yards, would seem to add weight to the idea of hibernation occurring in the egg form in the hop yard itself.

*History Elsewhere.*—The insect has an entirely different history elsewhere, and gave rise to many conflicting theories by students of this interesting insect before the full life-history was worked out. Probably the most complete study that has been made was published by the late Prof. C. V. Riley, then entomologist of the United States Department of Agriculture. This account appears in the report of that department for 1888. Briefly this life history as given by Professor Riley is as follows: "Hibernation takes place on different varieties and species of *prunus* (plum), and the little, glossy, black, ovoid eggs of the species are found attached to the terminal twigs, and especially in the more or less protected crevices around the buds. From this winter egg there hatches a stem-mother, which is characterized by being somewhat stouter, with shorter legs and honey-tubes than in the individuals of any other generation. Three parthenogenetic generations are produced upon *prunus*, the third being winged. This last is \* \* \* called the *migrant*, and it instinctively flies to the hop plant, which is entirely free from attack during the development of the three generations upon the plum. A number of parthenogenetic generations are produced upon the hop until in autumn, and particularly during the month of September, winged females are again produced. This is the return migrant, and she instinctively returns to the plum. Here she at once settles and in the course of a few days, according as the weather permits, produces some three or more young. These are destined never to become winged and are true sexual females. Somewhat later on the hop the true winged male, and the only male of the whole series, is developed, and these males also congregate upon the plum, on the leaves of which toward the end of the season they may be found pairing with the wingless females, which stock the twigs with the winter eggs."

*Possibilities of Winter Treatment.*—Professor Riley suggests that if the eggs of the species upon the plum trees were treated by sprays strong enough to kill them the hops could be thoroughly protected. The conditions that appear to exist in the hop-growing regions of California, as detailed above, are such that this method of control does not offer any promise of success. These field studies during the past two years have shown that here the life-history as given by Professor Riley is not at all followed out, since careful search of plum trees, both near to and distant from hop yards, has failed at all times with us to disclose

the presence of the hop aphid (*Phorodon humuli*) or its eggs. We are forced to conclude that, probably because of climatic conditions, this aphid has in this State a life-history much at variance with that given by Professor Riley and generally accepted as normal with the species.

It does not seem, therefore, that in this State any treatment of trees of the varieties of *prunus* (plums, prunes, green gages, etc.) for the destruction of the hibernating hop aphids, or their eggs, would be of value, since they are not there to be destroyed. The treatment of the soil of the hop yards during the winter with the idea of destroying the possible aphid eggs might accomplish more, but we do not think that there is much ground for hope of success, because of the practical difficulty of making such a treatment thorough enough to be effectual.

#### RESUMÉ.

To sum up, then, it seems that under our California conditions the hop aphids appear first in the spring as wingless parthenogenetic females (stem-mothers) upon the staminate (male) vines (p. 3). They reproduce rapidly here (p. 4), and occasional winged individuals soon appear (p. 4). These migrate to near-by vines, and the aphids are thus spread through the affected yard (p. 4). They confine their attack to the leaves of the vine until young hop cones are formed, and then attack these also (p. 4). The damage done is twofold, consisting of a reduction in the size and weight and also a loss of value to the hops, because of the poor aroma, due to the actual presence of the aphids in them (p. 5). Experiments with sprays made up of mixtures of kerosene emulsion and tobacco decoction (p. 5) and of whale-oil soap and quassia extract (p. 8) were entirely effective in controlling the aphids (p. 9). Other materials experimented with were not nearly so satisfactory in their effect as were the two described (p. 9). The hop aphid is quite readily identified (p. 9). The wingless and winged parthenogenetic females (p. 10) are followed late in the year by wingless oviparous females and winged males (p. 10). These are always found upon the late-growing male vines and in no other situations (p. 11). From the evidence at hand it would seem that hibernation of the aphids took place in the egg form in the hop yards (p. 11). This does not agree with the history of the insect elsewhere as published by Professor Riley (p. 12), and there seems to be no possibility of a successful winter treatment for the hop aphid under our California conditions (p. 13). Indeed, spraying with either of the washes described in this paper (pp. 5 to 9) so completely controls the hop aphid that the insect need not be considered a menace to the crop (p. 9) and the necessity of winter spraying is removed.

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